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Effects of Porous Mesh Groynes on Macroinvertebrates of a Sandy Beach, Santa Rosa Island, Florida, U.S.A.

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The use of porous mesh groynes to accrete sand and stop erosion is a relatively new method of beach nourishment. Five groyne, five intergroyne, and five control transects outside the groyne area on a beach near Destin, FL were sampled during the initial 3 mo after installment of groynes for *Arenicola cristata* (polychaete) burrow numbers, benthic macroinvertebrate numbers, and dry mass. Salinity, temperature, turbidity, and current velocity were measured at one location within the groyne site and control site. Current velocity was reduced and sand was accreted in the groyne site relative to the control site. Few significant changes or interactions (time × site) were found. Coquina (*Donax*), mole crab (*Emerita*), and several species of polychaete were not eliminated near groynes after installation of the groyne field. *Arenicola cristata* (polychaete) burrow numbers were higher near groynes. This is in contrast to dramatic changes often noted in the first few months after other types of beach nourishment techniques, such as sand pumping, where fauna can be completely eliminated.

The past quarter century has seen a dramatic increase in coastal development around the world and, because of the vulnerability of sandy beaches to storm damage and human activity, there has been an increased effort to combat coastal erosion (Komar, 2000). Beach erosion would occur regardless of development, but engineering activities often accelerate the erosion process (Hubertz et al., 1989). Florida has over 1,200 km of sandy beaches, many of which have been identified as critically eroding (Schmidt and Woodruff, 1999). Beach restoration projects in Florida have been conducted since the 1930s, but the first comprehensive erosion studies in Florida began in 1964 to address the environmental concerns of using dredged offshore material as beach fill (Hobbs, 1989).

Two traditional methods used to combat shoreline erosion are sand pumping, which uses dredged sand as beach fill; and groynes, which are typically permanent rock structures built at an angle from the shore to protect it from erosion and to trap sand (Mulvihill et al., 1980; Bodge and Rosen, 1989). Possible changes produced by traditional methods of erosion control include an accumulation of sand, altered sediment stability and composition, altered water flow, and burial of organisms (Goldberg, 1989; Meadows et al., 1998). The physical changes can produce small-scale spatial heterogeneity that can be of ecological importance (Petran and Kothe, 1978). Defining possible sources of variation, such as sediment grain size and near-shore current velocity, is important during and after beach nourishment (Stauble, 1989). Sand particle size, which may be changed by nourishment projects, can be a determining factor in habitat use by macroinvertebrates (Rakocinski et al., 1991; McLachlan, 1996; Snelgrove et al., 1999; Ronel et al., 2001). The amount of sand and the time frame over which it is deposited are also critical factors because of smothering action in determining effects of nourishment and the time of recovery (Greene, 2002). Beach nourishment can produce detrimental effects on macroinvertebrate populations, indicating the importance of how beach restoration is conducted (Dankers et al., 1984; Rakocinski et al., 1996). Most detrimental effects are seen immediately after beach nourishment because of changing beach conditions faster than organisms can respond (e.g., Reilly and Bellis, 1983; Peterson et al., 2000).

Dominant sandy beach macroinvertebrates of the southeastern United States include mole crabs, bivalve mollusks, amphipods, and polychaetes; a suite of organisms, in many cases to the level of genus, typical of sandy beaches worldwide, all of which play a role in the prey base of surf fishes, shorebirds, and crabs (McDermott, 1983; Brown and McLachlan, 1990). Macroinvertebrates are sensitive to external environmental stress, making them useful monitoring tools for aquatic ecosystems (Tesmer and Wefring, 1981). They respond to wave energy producing zonation in the near-shore area, leading to changes in faunal composition between the swash and sublittoral zones (Fleischack and deFreitas, 1989). *Donax* (coquina clam), *Emerita* (mole crab), and a few species of polychaete are common in the Gulf of Mexico swash zone (Nelson, 1988). The sublittoral zone is dominated by polychaetes, isopods, and amphipods (Nelson, 1988).

The present study involved the use of porous mesh groynes, which are constructed from nylon mesh attached to vertical posts, with the entire system designed to be removable after short time intervals. Porous mesh groynes protect beaches from erosion and accrete sand by slowing down littoral drift rather than deflecting littoral drift as produced by permanent rock groynes. They work on timescales of a few months rather than days as compared with sand pumping. Since they are designed to be removed after several months, longer-term problems associated with permanent rock structures are avoided.

In this study we assessed the effects of individual porous mesh groynes on the physical microhabitat and on macroinvertebrate abundance within one groyne field in the swash and sublittoral zones. Specific objectives of the study were to quantify macroinvertebrate diversity and density at both a control and a groyne site; and to determine if major declines in fauna leading to total absence occurred over the short timescale of several months after initial groyne installation, the time span when alternatives such as sand pumping often cause complete elimination of fauna. In addition, long-shore current velocity and sand particle size in the control and groyne sites were monitored.

Materials and Methods

Groyne and control sites.—The study area was located on Santa Rosa Island, west of Destin, FL (30°23′N 86°31′W), which faces the Gulf of Mexico to the south (Fig. 1). The area has been described as a low gradient platform, with low to moderate wave energy (Donoghue and Tanner, 1992), diurnal tides averaging 0.5 m in range, long-shore currents, and a subtropical climate. The beach consists of medium- to fine-grained quartz sand, typical in the northern panhandle of Florida.

The groyne field was established in December 2001 by Benedict Engineering Company (Tallahassee, FL) to examine the sand accretion properties of the mesh groyne system they manufactured (Nushore Removable Porous Groyne System™, website as of 2008: www.nushore.com/index.html). The company allowed us to monitor the groynes without interference after they were in place. We had no involvement in the design, placement, timing, arrangement, and installation of the groyne field, which precluded preinstallation sampling and consideration of issues dealing with a single

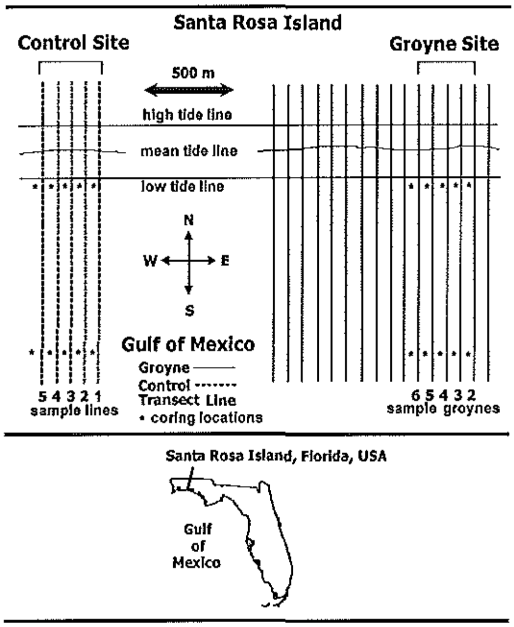

Fig. 1. Map of study site (30°23′N 86°31′W) in the northwestern Gulf of Mexico, Florida.

groyne field. Benedict Engineering Company had no involvement in the collection, processing, and interpretation of the biological samples.

The groyne field consisted of 16 mesh groynes placed 33 m apart labeled 1–16 east–west. Each groyne was 2.7 m high and made from three mesh panels sewn together. The mesh was attached to metal stanchions placed every 3 m along each groyne. Each mesh groyne started 12 m shoreward of the mean tide line (midway between high and low tides) and extended 50 m seaward, ending beyond the low tide line in approximately 2 m of water depth.

Transects were established on the west side of and immediately adjacent to mesh groynes 2–6 for a total of five groyne transects (Fig. 1). Five intergroyne transects, situated halfway between each mesh groyne (2–6), were demarcated by stakes and lines. Groynes (2–6) were chosen for sampling because they were similar in beach profile to the control site, to avoid edge effects in sampling the end groynes, and they were set up at the same point in time. Sampling began approximately 3 wk after the first groyne was installed (installation of all 16 groynes was accomplished over this time period, the first six being installed in the first week). The control site was located up-current 500 m west of the groyne site (Fig. 1). Five transects were demarcated with stakes and lines in the control site duplicating the spacing, placement, and distances (33 m apart, 50 m long) of the groyne transects.

Physical parameters.—Salinity, temperature, turbidity, and long-shore current velocity were recorded daily at 1400 hr at 1 m of water depth from one location in both groyne (groyne transect 3) and control (control transect 2) sites. Salinity was measured using a hand-held refractometer. Temperature (°C) was measured using a calibrated alcohol-based thermometer. Turbidity (NTU) was measured using a Hach turbidimeter. Long-shore current velocity (cm s^{-1}) was measured just above the bottom for 3 min using a F1 Universal flow meter.

Sediment samples were collected once a month from January to March 2002 at the high tide line from one location in both the groyne (groyne transect 3) and control (control transect 2) sites. Sediment was collected from three layers at each location: surface, 30 cm below the surface, and 60 cm below the surface. The sediment (200 g from each layer) was wet-sieved using a series of standard U.S. geologic sieves (150-µm, 250-µm, 300-µm, 355-µm, 425-µm, 850-µm, 1,000-µm, 1,400-µm, 2,000-µm, 2,380-µm mesh sizes). The geometric mean particle size was calculated for each layer of sediment. Physical parameters are presented as background information on the study sites and were not statistically compared. Average monthly values are reported.

Biological parameters.—All transects were sampled in a similar manner once a month from January to March 2002. This short time period represented the initial change to the environment where the most dramatic declines in fauna have been observed with other methods of beach nourishment. Sampling was done near the end of the month on days with calm weather to avoid wave interference and at low tide to limit variability due to animal migration with the tide, although with a tidal range of less than 1 m at the study sites this would have been minimal. Sampling of groyne, intergroyne, and control transects was accomplished within 2 d of one another.

Benthic macroinvertebrate infauna was sampled by coring. This did not include *Arenicola cristata*, a common polychaete too large and fast to be collected by coring, which was treated separately. To gain a better representation of the infauna across depths, samples were taken from both the swash and sublittoral zones. A 1-m^2 quadrat was placed in the swash zone just at the water's edge so the entire quadrat was underwater, and then in the sublittoral zone at a point 13 m from the seaward end of each transect. Three cylindrical cores (15-cm diameter, 18-cm depth) were taken inside the quadrat and combined, yielding one infaunal sample per transect from both the swash and the sublittoral zones. To decrease variability due to tidal fluctuations, all three cores from each quadrat were combined and initially placed in holding buckets so all transects were sampled as close to low tide as possible. Samples were then sieved using a 1-mm-mesh sieve. Sieve size was based on particle size of sand on the beach and the size of the common invertebrates found on beaches in the northern Gulf of Mexico. Sieved material was preserved in 5% formalin–seawater, with rose bengal added to stain biological material to make sorting easier. Organisms were then sorted from any remaining sediment and stored in 70% ethanol.

Invertebrates were identified to the lowest possible taxonomic rank. The number of species and the number of individuals of each species were counted for each quadrat. Abundance (number of individuals), richness (number of species), and the Shannon–Weiner diversity index (as eH') were calculated for groyne, intergroyne, and control sites by month for the swash and sublittoral zones (Krebs, 1999).

Arenicola cristata (lugworm polychaete) burrows (large 1-cm-diameter holes visible on the surface) were counted within a 1-m^2 quadrat that was moved along the transect starting at the edge of the water to the end of the groyne. Average number of burrows per square meter was used as a single datum for each transect.

After individuals from the cores were identified, specimens were placed in a drying oven for 24 hr. All individuals of a given species from each quadrat were combined and weighed on an analytical balance to obtain dry mass. Mollusks were removed from shells before drying. Dry mass of individuals was combined into the following categories: polychaetes, bivalves, and crustaceans; and separated by swash and sublittoral zones. Nematodes were considered accidental captures trapped on larger particles that did not go through the sieve and were not utilized in the analyses.

Statistical analysis.—The number of polychaete burrows and dry mass for each category (by swash and sublittoral zones) for groyne ($n = 5$), intergroyne ($n = 5$), and control ($n = 5$) transects for the 3 mo were compared using a two-way ANOVA with a Tukey multiple comparison test following significant ANOVA outcome (Zar, 1999). Seven two-way ANOVAs resulted in a total of 21 main effects tests. Significance of each P value was judged using the false discovery rate approach to adjust for multiplicity using an

TABLE 1. Average monthly values ± SD of daily measures for salinity, water temperature (°C), turbidity (NTU), and current velocity (cm s^{-1}); and geometric mean particle size (GMPS; mm) at the surface, 30 cm below surface, and 60 cm below surface collected once each month.

Parameters	January 2002	February 2002	March 2002
Salinity	35.00 ± 3.06	34.00 ± 3.21	35.00 ± 2.31
Water temperature	14.00 ± 2.30	17.00 ± 2.24	19.00 ± 2.56
Turbidity (groyne)	1.62 ± 1.03	1.19 ± 0.28	6.95 ± 5.81
Turbidity (control)	1.58 ± 1.02	1.33 ± 0.62	7.43 ± 5.57
Current (groyne)	4.63 ± 6.28	10.25 ± 8.68	5.09 ± 4.16
Current (control)	6.22 ± 23.92	12.98 ± 9.29	10.35 ± 10.47
GMPS surface (groyne)	0.4108	0.4019	0.4154
GMPS surface (control)	0.4036	0.3799	0.4139
GMPS 30 cm (groyne)	0.4100	0.3572	0.4225
GMPS 30 cm (control)	0.4086	0.3678	0.4038
GMPS 60 cm (groyne)	0.4163	0.3819	0.4138
GMPS 60 cm (control)	0.4022	0.3921	0.4019

experimentwise $\alpha = 0.05$ (Benjamini and Hochberg, 1995).

RESULTS

Physical parameters.—Salinity and temperature were the same among sites throughout the study, with an increase in temperature over time (Table 1). Turbidity was highest in March and varied among sites (Table 1). Current velocity was consistently lower in the groyne site than control site for all 3 mo (Table 1). The groyne site had a slightly larger geometric mean particle size, except for the February control site at 30 and 60 cm below surface, but the difference between the largest and smallest geometric mean value across all transects was only 0.0653 mm (Table 1).

Biological parameters.—Individuals of 14 infaunal species were found in the samples (Table 2). The bivalve *Donax variabilis,* the crustaceans *Emerita talpoida* (anomuran, mole crab), *Ancinus depressus* (isopod), and *Haustorius jayneae* (amphipod), and the polychaete *Scolelepis squamata* were the numerically dominant fauna, with the swash zone having three times the abundance of the sublittoral zone. In any one sample from an individual transect abundance ranged from 0 to 31 and richness ranged from 0 to 5. Mean abundance values ranged from 0.2 to 15 and mean richness values ranged from 0.2 to 2.4 (Table 3). The Shannon–Weiner diversity eH' value calculated for each site ranged from 1 to 5.75 (Table 3).

The mean number of *Arenicola cristata* polychaete burrows per square meter ranged from 0 to 1.8 and a significant difference was found for sites and months, but not for interaction (Table 4). For groyne, intergroyne, and control transects the mean number of burrows was greatest in January and lowest in February. In all months the means of intergroyne and groyne transects were higher than the control transects and similar to one another.

The polychaete, bivalve, and crustacean dry mass data show variability over sites and months, but no clear direction in either case (Table 5). Only two statistical tests, months for sublittoral polychaetes and months for sublittoral crustaceans, were significant (Table 6). Dry mass for polychaetes was slightly greater in the sublittoral zone than in the swash zone. Dry mass for bivalves was substantially greater in the swash zone than in the sublittoral zone and an order of magnitude greater than dry mass of polychaetes and crustaceans. Dry mass for crustaceans was similar between swash and sublittoral zones, except for March when the swash zone had larger values (Table 5).

TABLE 2. List of species.

Polychaetes	Bivalves	Crustaceans	Other Groups
Paraonis fulgens	*Donax variabilis*	*Ancinus depressus*	*Mellita tenuis* sand dollar
Phyllodoce arenae	juvenile sp. A	*Emerita talpoida*	Nemertea sp. A
Scolelepis squamata	juvenile sp. B	*Haustorius jayneae*	Nemertea sp. B
		Spilocuma wallingi	Nematoda sp A

TABLE 3. Summary of diversity measures from infaunal cores: mean abundance ± SE = total number of individuals, mean richness ± SE = number of different species, eH' = Shannon–Weiner function.

Measures	Zones	Sites	January 2002	February 2002	March 2002
Abundance	Swash	Groyne	4.2 ± 1.46	7.4 ± 1.36	9.4 ± 59
		Intergroyne	8.8 ± 4.64	6.4 ± 1.57	15 ± 4.39
		Control	11.2 ± 4.12	7.2 ± 1.77	2.0 ± 0.84
	Sublittoral	Groyne	2.4 ± 0.93	2.8 ± 1.16	3.8 ± 1.66
		Intergroyne	3.6 ± 2.46	4.4 ± 1.36	1.2 ± 0.8
		Control	0.2 ± 0.2	4.8 ± 0.86	0.8 ± 0.58
Richness	Swash	Groyne	2.2 ± 0.73	2.2 ± 0.37	1.8 ± 0.2
		Intergroyne	1.6 ± 0.4	2.0 ± 0.32	2.2 ± 0.37
		Control	1.6 ± 0.24	2.4 ± 0.4	1.4 ± 0.6
	Sublittoral	Groyne	1.6 ± 0.68	1.8 ± 0.8	2.0 ± 0.84
		Intergroyne	1.4 ± 0.68	2.8 ± 0.73	0.8 ± 0.58
		Control	0.2 ± 0.2	1.8 ± 0.2	0.8 ± 0.58
eH'	Swash	Groyne	4.05	2.53	1.68
		Intergroyne	2.61	2.16	2.34
		Control	1.55	5.10	4.35
	Sublittoral	Groyne	3.86	4.66	3.42
		Intergroyne	3.86	5.75	3.78
		Control	1	2.89	4.01

DISCUSSION

Groyne and control sites.—The porous mesh groyne system is an alternative to permanent rock groynes or sand pumping as a nourishment method. It is designed to be removable with the intent that the system could be installed during months of the year when beach use is low and then removed during months when beach use is high (nontourist, tourist seasonal beach use). As a management tool the removable nature of the system would also allow for installation/removal to be based on natural cycles of organisms to try and minimize nourishment interference with things such as recruitment events.

The groynes were left in place only an additional 3 mo after sampling ended before being removed. During this time the engineering company made numerous modifications to the system, which disrupted the ability to sample. Accretion of sand to the beach area within the groynes occurred during the time frame of study and resulted in a 10-m seaward movement of mean high tide line over 3 mo (measurements made by communication from Benedict Engineering Company, Tallahassee, FL—contact information provided on website listed in Materials and Methods section). This did not occur in the control site.

Physical parameters.—Most sand-pumping restoration projects apply large volumes of sediment in a short time period, days to weeks, which is often dissimilar in composition to the original sand of the nourished site. In the present study the sediment was deposited gradually over longer periods of time, weeks to months. The use of porous groynes resulted in grain sizes within the groyne area remaining similar over time to the control area.

Salinity showed slight variability over time. Water temperatures increased monthly, as expected, because of a seasonal change from late winter to early spring. Increasing water temperatures may be responsible for some of the temporal changes. Differences in turbidity values between the groyne and control sites were small and variable. A slight reduction in flow was

TABLE 4. Mean ± SE for number of *Arenicola cristata* polychaete burrows m^{-2}.

Sites	January 2002	February 2002	March 2002
Groyne	1.44 ± 0.18	0.89 ± 0.12	1.25 ± 0.20
Intergroyne	1.80 ± 0.12	0.89 ± 0.06	1.50 ± 0.24
Control	0.00 ± 0.00	0.42 ± 0.08	0.50 ± 0.11

Statistical results from two-way ANOVA: months $F(2,36) = 11.5$, $P = 0.0001$*; study sites $F(2,36) = 12.9$, $P = 0.00006$*; interaction $F(4,36) = 0.7$, $P = 0.57$.

* Considered significant using false discovery rate multiplicity control.

TABLE 5. Mean ± SE of dry mass (mg) from infaunal cores.

Fauna	Zones	Sites	January 2002	February 2002	March 2002
Polychaete	Swash	Groyne	0.00 ± 0.00	0.70 ± 0.47	0.00 ± 0.00
		Intergroyne	0.00 ± 0.00	0.51 ± 34	0.00 ± 0.00
		Control	0.00 ± 0.00	0.13 ± 0.08	0.20 ± 0.13
	Sublittoral	Groyne	0.18 ± 0.09	0.86 ± 0.41	0.19 ± 0.13
		Intergroyne	0.18 ± 0.18	0.69 ± 0.57	0.00 ± 0.00
		Control	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.04
Bivalve	Swash	Groyne	13.15 ± 8.13	153.67 ± 50.20	260.41 ± 107.45
		Intergroyne	159.85 ± 152.28	209.40 ± 69.83	397.47 ± 171.70
		Control	369.06 ± 137.46	86.51 ± 52.06	6.88 ± 4.63
	Sublittoral	Groyne	0.44 ± 0.44	19.81 ± 19.81	7.89 ± 7.89
		Intergroyne	0.00 ± 0.00	1.38 ± 1.38	2.92 ± 1.91
		Control	0.00 ± 0.00	3.05 ± 1.59	7.66 ± 7.66
Crustacean	Swash	Groyne	4.03 ± 1.44	13.97 ± 6.89	25.14 ± 17.80
		Intergroyne	5.38 ± 1.45	14.79 ± 5.44	31.06 ± 13.96
		Control	1.33 ± 0.70	6.48 ± 3.65	13.34 ± 9.65
	Sublittoral	Groyne	1.32 ± 0.81	17.07 ± 13.15	4.07 ± 1.70
		Intergroyne	4.85 ± 4.82	26.94 ±11.27	0.90 ± 0.90
		Control	0.00 ± 0.00	19.25 ± 9.12	9.90 ± 9.90

observed within the groyne site vs the control site for all months, which is probably part of the reason for sand accretion to the beach at the groyne site.

Biological parameters.—Abundance, richness, and the Shannon–Weiner diversity index results suggest three conclusions. First, diversity is generally low in all sites. Second, diversity and abundance are highly variable from month to month and among sites, indicating a lot of small-scale patchiness. Third, complete elimination of typical sandy beach fauna did not take place within the groyne site.

Abundance was higher in the swash zone, whereas species richness was higher in the sublittoral zone. This suggests that lower energy conditions increase the ability to support more species, whereas individuals capable of handling higher wave energy have sufficient resources for maintaining large populations. Macroinvertebrate diversity on sandy beaches is primarily affected by two factors, wave energy and sand particle size (McLachlan, 1983). Sheltered beaches are typically higher in species diversity and density than exposed beaches (Gauld and Buchanan, 1956). Distributions of sand beach macroinvertebrates are generally patchy because of biological aggregations, localized food concentrations, and tidal as well as seasonal migrations (Loesch, 1957). Macroinvertebrate species diversity typically increases from high to low tide lines, may decrease just below mean low tide line, and then increase further offshore (Brown and

TABLE 6. Statistical results for mean dry mass from infaunal cores from two-way ANOVA.

Fauna	Zones	Months	Sites	Interaction
Polychaete	Swash	$F(2,36) = 4.323$ $P = 0.02077$	$F(2,36) = 0.281$ $P = 0.75629$	$F(4,36) = 1.077$ $P = 0.38220$
	Sublittoral	$F(2,36) = 9.118$ $P = 0.0006$*	$F(2,36) = 4.653$ $P = 0.0159$	$F(4,36) = 3.600$ $P = 0.0143$
Bivalve	Swash	$F(2,36) = 0.375$ $P = 0.6901$	$F(2,36) = 1.120$ $P = 0.3372$	$F(4,36) = 3.059$ $P = 0.0287$
	Sublittoral	$F(2,36) = 0.887$ $P = 0.4208$	$F(2,36) = 0.875$ $P = 0.4254$	$F(4,36) = 0.527$ $P = 0.7164$
Crustacean	Swash	$F(2,36) = 3.741$ $P = 0.0334$	$F(2,36) = 1.040$ $P = 0.3639$	$F(4,36) = 0.166$ $P = 0.9541$
	Sublittoral	$F(2,36) = 5.650$ $P = 0.0073$*	$F(2,36) = 0.139$ $P = 0.8709$	$F(4,36) = 0.440$ $P = 0.7787$

* Considered significant using false discovery rate multiplicity control.

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McLachlan, 1990). The pattern of distribution found in the present study fits the general pattern reported for most sandy beaches.

Polychaetes were the third most numerous group of macroinvertebrates. Polychaete burrows belonged to one species, *Arenicola cristata*, and were not found in the swash zone. Burrow number was greater in the groyne site. *Arenicola cristata* is limited to beaches that are stable enough to support their semipermanent burrows (Brown and McLachlan, 1990). It is possible that reduced current velocity in the groyne site may have provided the large polychaete a better environment for creating burrows by offering a protective microhabitat. Because the sites could not be sampled before groyne placement, it is not possible to attribute the greater number of burrows to the presence of the groynes; but it is possible to conclusively state that they were not absent near the groynes, which is the pertinent conclusion relative to the question of interest. The dry mass measures came from three species of small polychaete present in the cores and did not include *A. cristata*. The dry mass of polychaetes was highly variable over time within sites. Reilly and Bellis (1983) found that polychaetes were the only macroinvertebrates to inhabit the nourished zone after beach nourishment at Fort Macon, NC. Lack of impact may be due to burrowing ability. Two species of polychaete were able to burrow upward through 0.9 m of material in a laboratory experiment (Mauer et al., 1982). On the other hand, Mauer et al. (1982) also found that mortality of polychaetes increased as the silt-clay fraction of sediments increased. Sediment deposition from nourishment projects may decrease polychaete numbers, even though they are relatively resilient to sediment disturbance, because of changes in sediment composition (Saloman and Naughton, 1984). This suggests that the results of the present study may be related to the slow accretion of sand with similar particle characteristics across sites.

Bivalves in the genus *Donax* are found on sandy beaches in many parts of the world and are often an abundant component of the intertidal fauna (Edgren, 1959; Wade, 1967). *Donax variabilis* was the most numerous macroinvertebrate found in the present study. No significant differences were found for the dry mass among sites within the sublittoral and swash zones or among time periods. The swash zone had many times more *Donax* than the sublittoral zone; an expected result as the swash zone is the typical habitat for *Donax*. The lack of significant temporal changes may be related to the time frame of the present study. *Donax variabilis* populations in Florida have seasonal fluctuations, with maximum densities occurring in summer (Edgren, 1959). The present study was conducted during winter–early spring and would not have included summer seasonal population fluctuations. Reilly and Bellis (1983) studied a beach nourishment project that eliminated the *Donax* population. They postulated that the adult *Donax* population was eliminated because of sediment smothering and larval recruitment was inhibited because of different sediment characteristics in the time period immediately after nourishment. A beach nourishment study conducted in Bogue Banks, NC found a drastic decline of *Donax* immediately after nourishment (Peterson et al., 2000). The *Donax* population began to recover only after many months, and Peterson et al. (2000) suggested that the poor match of nourishment sand with previous sand, including altered particle size and increased shell hash, was responsible for the decline. In contrast, Gorzelany and Nelson (1987) found no significant negative effects on *Donax* populations due to a nourishment project on Melbourne Beach, FL. They concluded that the lack of negative effects might be a result of a close match of sediment properties between the fill sediment and the natural sediment. The lack of significant effects among sites in our study, with the most important conclusion being that *Donax* was not absent near the groynes, was probably due to bivalves being able to resist smothering due to slow sediment accretion and sediment properties remaining consistent across sites.

Striking similarities occur in types of crustaceans found on sandy beaches in various parts of the world (Dahl, 1952). Crustaceans represented the second largest group in the present study and were dominated by a few species, primarily the mole crab *E. talpoida*, the haustoriid amphipod *H. jayneae*, and the isopod *Ancinus depressus*. Crustacean dry mass showed significant temporal differences, but no significant difference was found between sites. Populations of *E. talpoida* exhibit large seasonal fluctuations, with changes taking place in relatively short periods of time (Matta 1977; Diaz, 1980). The effect of beach nourishment on *E. talpoida* varies among areas studied. Hayden and Dolan (1974) observed no mortality of *E. talpoida* as a result of nourishment and attributed the lack of mortality to nourishment sand being similar in composition to the prenourishment beach sand. Reilly and Bellis (1983) found elimination of *E. talpoida* populations on a nourished beach where the nourishment sand was obtained from dredged harbor sediment, drastically different in character from the original beach sediment. The nourished beach was recolonized by *E. talpoida* several months later.

Amphipods and isopods generally reach peak abundance in Florida during the late spring and summer months and a minimum abundance from late fall through May (Nelson, 1985). *Haustorius jayneae* primarily occurs in the swash zone and on the first sand bar (Foster and Lecroy, 1991). The spatial distribution patterns of amphipods can be very complex and are often separated by wave energy conditions (Dexter, 1967). Reilly and Bellis (1983) found a total disappearance of amphipods in nourished areas after sand pumping. Amphipods had still not returned to the nourished beach after 3 mo. In contrast, Charvat (1987) could not find a significant effect on abundance or diversity of amphipods due to beach nourishment on the central Atlantic coast of Florida. The nourishment sediment used in that study was a close match to the natural beach sediment. Once again this suggests that the results of the present study may be related to the slow accretion of sand with similar particle characteristics across sites with no elimination of typical crustacean fauna in the groyne site.

Experimental design considerations.—It is difficult to detect small biological effects resulting from beach nourishment projects because of high levels of natural variability related to seasonality and spatial patchiness of organisms (Nelson, 1985; Schoeman et al., 2000). Because of constraints on the study beyond our control, multiple sets of groyne fields could not be replicated. The groyne field was not established for the purpose of a scientific study about the beach community; we took advantage of an opportunity that presented itself in the form of a large and expensive project designed to add sand to a beach. Therefore the statistical results only apply to the small scale of individual groynes/transects (33-m spacing). This constraint would not have prevented our ability to determine total absence, which is the relevant question related to other methods of beach nourishment within the first few months after nourishment procedures. Variability due to annual cycles was not pertinent to this study since the porous mesh groynes are not designed to be left in place for long periods of time and were removed after several months.

Summary.—The porous mesh groynes did not substantially alter the physical parameters, particularly sand particle size characteristics (on the basis of the range of the geometric mean particle size of 0.3572–0.4225 mm). The results indicated no elimination of common macroinvertebrates in the groyne transects that had been seen immediately after sand pumping nourishment projects (Greene, 2002). We suggest that this may be due to the gradual accumulation of sand, with characteristics similar to sand already on the beach, over a time span that allows organisms to adjust to the changing sedimentary environment.

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